RFQ Fabrication Plan, Schedule and QC

PXIE RFQ Fabrication Readiness Review

LBNL – June 26, 2013

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Fermilab

Topics

- Fabrication plan
- Schedule
- Quality control
- Tolerance analysis

Fabrication Plan

- A plan has been developed to coordinate the RFQ fabrication using the LBNL shops and select outside vendors
- Key fabrication tests used to minimize risk
- Priority to be given to module construction (vs. subcomponents) due to schedule critical path
- LBNL shop and vendors have all necessary equipment in place

Fabrication Plan (cont'd)

- Multiple operations on various aspects of fabrication to take place in parallel
- Dedicated machines and operators selected
- Oversight of fabrication coordination by Rick Kraft, Deputy Central Shop Manager
  - In house services: machining, tooling, cleaning, CMM, etc.
  - Outside vendor liaison: gun drill, e-beam weld, braze (all vendors identified)

Fabrication Steps

- Vane rough profile machining
- Cooling passage gun drilling*
- Cooling channel e-beam plug weld*
- Port machining: vacuum slots, tuners, pi-mode rods, thread inserts, sensing loops, cooling taps, joint plate features
- Finish profile: cavity walls, pi-mode holes, vane cutbacks

*outside vendor

Fabrication Steps (cont'd)

- Braze wire groove machining
- Vane tip modulation cutting
- Pre-braze vane cleaning
- Assembly and module brazing*
- Module end seal machining

* outside vendor

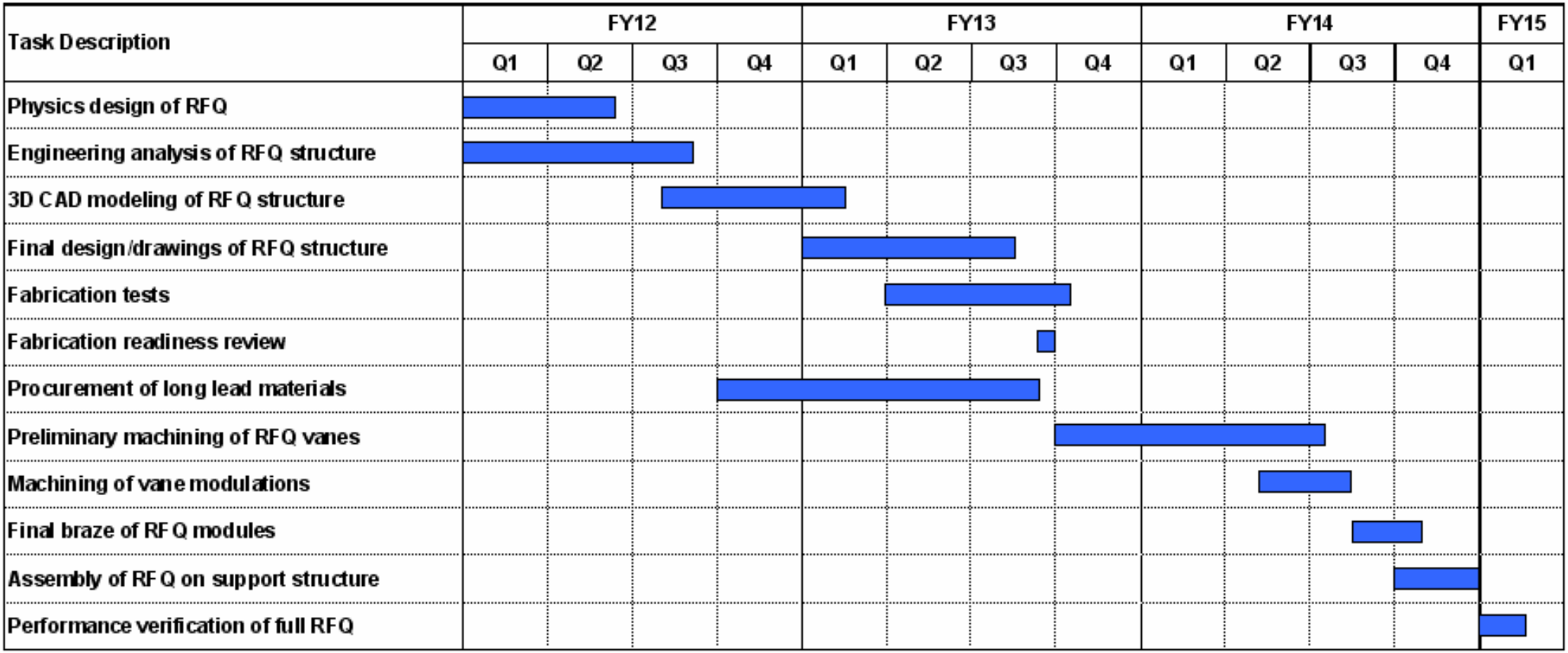
Fabrication Work Flow

- 16 vanes (8 horizontal, 8 vertical) to be cycled through each operation in sequence
- Outside work to be organized in groups of four (one module)
- Numerous different fabrication tasks taking place in parallel
- Subcomponent fabrication tasks to be used as filler

Schedule

- Detailed MS Project resource loaded schedule/cost estimate has been developed
- Engineering schedule and cost estimates are in line with shop estimates and capabilities
- Manpower is available and identified (design and engineering, machinists, technicians)
- ~15 months total for module fabrication
- Ready to start production after this review

Schedule Summary



Refer to MS Project RLS for details

Quality Control Measures

- Material certifications and testing
- Dimensional checks (CMM)
- Vacuum leak checks
- Water flow measurement
- Visual examination
- Bead pull measurements
- QC travelers

Quality Control Steps

- Review of vane Cu material certs, test fire samples in oven
- Rough measurement of T-shaped vane pieces (min. dims.)
- Flow and leak checks of cooling passages after gun drill, e-beam weld
- CMM of ports on vane back faces, including flatness for fiducial
- Vane dimensional checks before modulating (on machine)
- Detailed CMM measurement of vanes after modulating (vane tips, fiducial surfaces) while still on mounting plate
- Cooling passage leak and flow check
- Visual inspection of vanes prior to braze assembly
- CMM check at module ends prior to braze
- Bead pull prior to module braze (Module 2)
- Post-braze CMM check at ends
- Brazed cavity leak check and cooling passages
- Post-braze bead pull (Module 2)
- Visual inspection module end sealing surfaces
- Full RFQ bead pull

Vane QC Traveler

Module 1 Vertical, Top Vane
Fabrication Traveler (1VT)

Raw Material	Drawing #	Start Date	End Date	Machine	Machinist Signature
Label Raw Copper	27I671 - Sheet 1				
QA Check	**QA Signature**	**Comments:**			
Test Sample					
Material Spec Sheet Check					
Dimensions & General Condition					
Visual Inspection					

Rough Profile	Drawing #	Start Date	End Date	Machine	Machinist Signature
Rough Profile Machining	27I671 - Sheet 2				
QA Check	**QA Signature**	**Comments:**			
Visual Inspection					

Gun Drill (Outside Vendor)	Drawing #	Start Date	End Date	Machine	Machinist Signature
Wall Channel (1)	27I671 - Sheet 3				
Vane Channel (1)	27I671 - Sheet 3				
QA Check	**QA Signature**	**Comments:**			
Visual Inspection					

E-Beam Weld (Outside Vendor)	Drawing #	Start Date	End Date	Machine	Machinist Signature
Weld Copper Plugs (provided by LBNL)	27I671 - Sheet 4				
QA Check	**QA Signature**	**Comments:**			
Visual Inspection					
Vacuum Check					
- Wall Channel (1)					
- Vane Channel (1)					
Flow Check					
- Wall Channel (1)					
- Vane Channel (1)					

Vane QC Traveler (cont'd)

Port Machining	Drawing #	Start Date	End Date	Machine	Machinist Signature
Create Datum Feature A (Back Side)	27I671 - Sheet 5				
Vacuum Ports (Slots & Relief)	27I671 - Sheet 5	Comments:			
Slug Tuner Ports	27I671 - Sheet 5				
Sensing Loop Ports	27I671 - Sheet 5	Start Date	End Date	Machine	Machinist Signature
Pi-mode Rod Ports	27I671 - Sheet 5				
Cooling Water Ports	27I671 - Sheet 5				
Threaded Insert Ports	27I671 - Sheet 5				
Joint Plate Grooves	27I671 - Sheet 5				
QA Check	**QA Signature**				
Visual Inspection					
CMM Datum Feature A & All Port Sizes and Locations					

Finish Profile Machining	Drawing #	Start Date	End Date	Machine	Machinist Signature
Cavity Profile Machining	27I671 - Sheet 6				
Pi-mode Rod Clearance Holes	27I671 - Sheet 6				
Cutback Machining	27I671 - Sheet 6				
QA Check	**QA Signature**	Comments:			
Protective Foam/Cover on Cavity Surf.					
Visual Inspection					

Modulation Machining	Drawing #	Start Date	End Date	Machine	Machinist Signature
Cut Modulations in Vane Tips	27I671 - Sheet 7				
QA Check	**QA Signature**	Comments:			
CMM Cavity Profile					
CMM Port Locations					
CMM Modulations					
CMM Pi-mode Rod Clearance Holes					
Protective Foam/Cover on Vanetips					
Visual Inspection					

Tolerance Analysis

- Numerous factors considered: machining tolerances/stack up, slug tuner range, RF analysis uncertainty, pre-braze bead pull, post-braze distortion, vacuum operation, frequency shift due to RF heating
- Slug tuners must cover range of possible field tilt and frequency error
- Differential cooling control primarily used to offset frequency shift from RF heating

Tolerance Analysis

- Slug tuner range: ±1.4 MHz
  - based on analysis, verified by preliminary IMP tests
- RF module analysis: within <400 kHz
  - good agreement among codes – 3D CST MWS, ANSYS, ACE3P
  - measurements of IMP half module look promising
- Machining errors: ±150 kHz
  - specified tolerances not difficult to meet
- Braze distortion: likely ~100 kHz
  - less distortion from modified clamp design

Tolerance Analysis

- Operation with vacuum: -30 kHz
  - very small effect
- Pre-braze bead pull of first module will be used to confirm machining and RF analysis
  - alternative to cold model
- Water temperature tuning: ~16 kHz/°C
  - sufficient to actively tune out RF heating effects
- Extensive tolerance analysis of the physics design previously carried out (J. Staples)
  - overall, design has been found to be very error tolerant